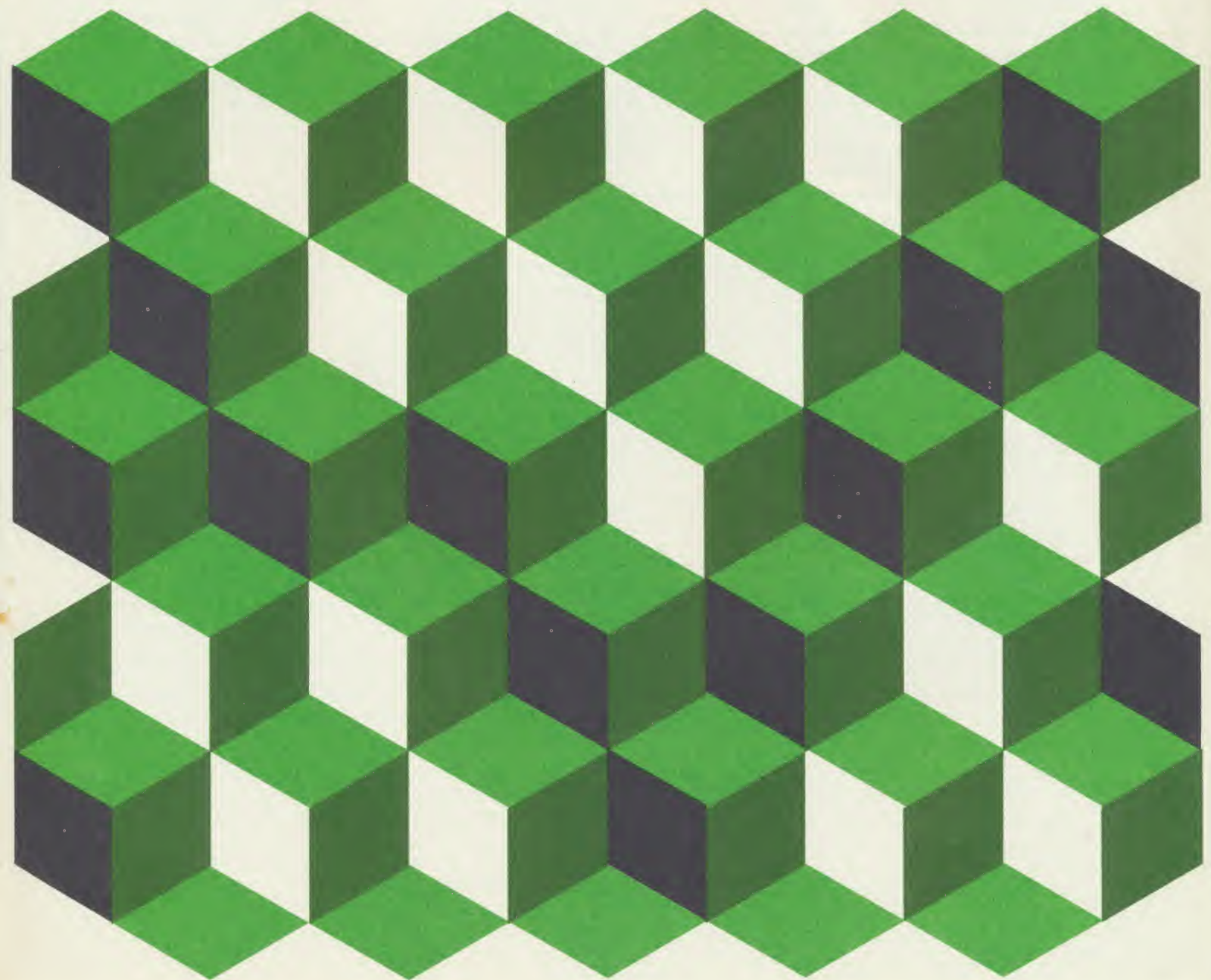


APT III
NUMERICAL
CONTROL



NUMERICAL CONTROL WITH APT III

Owners of numerical control equipment — automatic milling machines, drill presses and other machine tools — can now program the most complex operations

- ☐ with the full power of APT III
- ☐ using UNIVAC Data Processing Center services
- ☐ via telecommunications.

Numerical control (N/C) has introduced a new era in manufacturing. The use of instructions on punched or magnetic tape to control machine tools for automatic operation offers direct economies such as:

- ☐ short runs of complex parts can be produced profitably
- ☐ designs can be complex, and changed close to production time
- ☐ quick manufacturing lead times
- ☐ less need for special jigs and fixtures
- ☐ accurate, quality work
- ☐ smoother production control
- ☐ direct labor and setup savings.

In a word, N/C is flexible, profitable automation for the metalworking industry regardless of size. It is estimated that in the near future most metalworking plants in competitive production will have an N/C installation.

APT programming by computer offers the most economic, accurate approach, since the customer pays only for the actual computer time used.

APT III

The APT (Automatically Programmed Tools) system is the most versatile answer to producing computer-assisted programs for N/C. APT III gives numerical control new power and reliability with greater savings and convenience. In an English-like, production-oriented language, metalworking personnel describe the geometry of a metal part and just how they want it cut. Using this information and the instructions of the APT master program, the computer calculates the many, many individual motions the machine tool must follow to produce the desired part.

APT III is the result of the coordinated research and development efforts of government, business, and educational in-

stitutions. Now under the management of the Illinois Institute of Technology Research Institute, APT continues to be developed into a more useful tool. The Univac Division of Sperry Rand has been a member of this group from the beginning. It was quickly recognized that the UNIVAC 1107 Computer was an ideal vehicle for APT. Its large drum memory, its ability to do concurrent processing and its on-line telecommunications facility make the UNIVAC 1107 unexcelled for complex APT work in speed and economy. APT now has widespread acceptance in the metalworking industry as the standard N/C language. And APT III used on the UNIVAC 1107 Computer is the present ultimate in its capability.

THE APT III COMPUTER PROGRAM

Section Zero: The APT Executive

This part of the program directs the activity of the computer units with APT. It makes efficient use of the UNIVAC 1107 magnetic drum memory and other advanced features to give a reliable, low-cost APT III program. The APT part program is read into the computer from cards. All work is done by the UNIVAC 1107 and the control tape is punched

UNIVAC		APT III		UNIVAC 1107	
AUTOMATICALLY PROGRAMMED TOOLS					
NUMERICAL CONTROL PART PROGRAM 12L9099-3 OPER.10		PART PROGRAMMER L. RAY REEVES		DATE 7-21-64 PAGE 1 OF 3 PAGES	
(SYMBOL)	() DEFINITION OR INSTRUCTION	TWX		SEQUENCE NO.	
1	6 8 10 20 30 40 50 60 73 80 90				
PARTNO	12L9099-3 OPER. 10 (MACHINE TOP OF WALLS)			10	
	CLPRNT			20	
	MACHIN/GECENT, 3			30	
	INTOL/.005			40	
	OUTTOL/.005			50	
	CUTTER/1,.5			60	
SET PT	POINT/-2,1.5,10			70	
C1	CIRCLE/4,.8,12			80	
PS	PLANE/0,0,1,8.75			90	
	FRAM/SET PT			100	
	INDIRV/0,-10,-.2			110	
	G0/T0,C1,T0,PS,100			120	
C2	CIRCLE/XSMALL,(L2=LINE/(POINT/6.5,.5),ATANGL,70),YLARGE,IN,C1,8			130	
	RADIUS,.625			140	
	TLLFT,G0LFT/C1,TANT0,C2,15 ** REDUCE FEEDRATE			150	
	G0FND/C2,TANT0,L2			160	

Figure 1.

directly. There is no peripheral computer needed (as is the case with N/C on other computers not as advanced as the UNIVAC 1107). Thus, APT III on the UNIVAC 1107 results in savings of many dollars of computer time.

Section One: The APT Translator

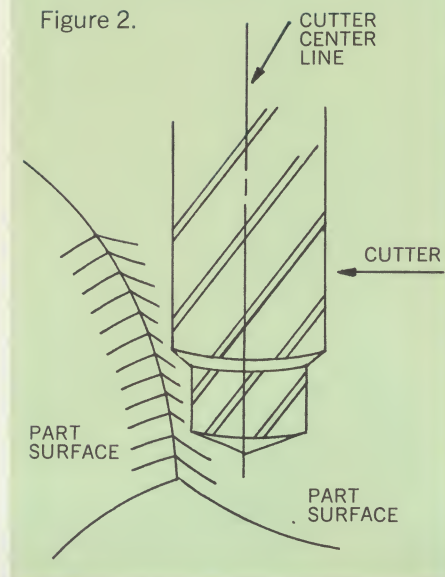
APT is designed for production men to use. The language and format are very much like the English language. The computer, however, operates most efficiently with numbers and tables of words. Section 1 of APT makes the transition, translating the English-like part program into the internal computer language, PROTAP. This section of APT also develops the standard format (canonical form) for the surfaces of the part to be cut, performs the calculations specifically called for by the part programmer (square roots, multiplications, sines and cosines, etc.), and prints and card-punches data requested by the part programmer. Figure 1 shows a portion of a typical APT part program. It illustrates the preliminary information (Nos. 10 to 60), geometric definitions (Nos. 70 to 90), and cutter instructions (Nos. 100 to 160).

Section Two: The APT Pathfinder

The Arithmetic Element (ARELEM) is the pathfinder or key element of APT. ARELEM is actually a geometric sub-program which solves complex and difficult problems. A new ARELEM was recently issued by the APT Long-Range Program. It incorporates the best thinking of the country's experts and makes APT III indispensable for 3-axis and 5-axis contour machining.

From the mathematical descriptions of the cutter and of the part to be cut, Section II computes the short, straight-line cuts that will be used to approximate the mathematically defined surface to the required tolerance. It also computes the cutter offsets needed to produce these cuts. The results, then, are a series of locations for the center line of the cutter at the proper depth of cut.

Some idea of the problem can be gained from Figure 2. The cutter center line bears no simple analytic relation to the part surface. Though it may touch



the part surface in more than one place, the "gouge" and "extra metal" tolerances must be maintained in the straight line cuts. Therefore, the cutter must start and stop without running into the part at the ends of the cut.

Section Three: The APT Format and Reference System Manipulator

Section III is not used in every APT program. It is called only when needed. In the UNIVAC 1107 APT III System, Section III can do the following:

1. Transform the cutter location data to a new system of coordinates.
2. Print cutter locations.
3. Change UNIVAC 1107 C/L Tape format to IBM 7090/7094 C/L Tape format.
4. Change IBM 7090/7094 C/L Tape format to UNIVAC 1107 C/L Tape format.
5. Change UNIVAC 1107 C/L Tape format to UNIVAC SYMPAC format.

The last three capabilities have been added to allow UNIVAC 1107 users the widest scope in the selection of postprocessors. Through the use of the APT III to SYMPAC translator, for example, the unmatched power of APT III can be coupled to the extensive library of the UNIVAC Solid State 80/90 SYMPAC numerical control postprocessors. This feature is useful for older or specialized control systems for which UNIVAC 1107 APT III postprocessors may not be available.

Section Four: The APT Postprocessor

A postprocessor is a computer program that tailors the generalized data produced by the earlier sections of APT to run a particular combination of machine tool and control system. The main areas

of tailoring concern the geometry and dynamics of the machine tool and the format used by the control system. An example of how machine tool dynamics must be handled is the generation of acceleration and deceleration commands. After specifying a desired feed-rate, the APT part programmer need not concern himself with the way this feed-rate is maintained. The control system-machine tool can produce only a limited acceleration and deceleration and it is a postprocessor function to resolve these limitations to achieve the desired feed-rate.

The major control system builders are producing integrated "families" of postprocessors in a computer-independent language (generally FORTRAN). Univac is ready and able to implement these major families on UNIVAC APT computers. An integrated postprocessor family—for example Cincinnati Acramatic or General Electric GECENT—can be used for many different machine tools that use the particular series of controls.

UNIVAC DATA PROCESSING CENTERS—APT SERVICES

UNIVAC Data Processing Centers offer a profitable approach to computer-assisted N/C for manufacturers with either one or many numerically controlled machines. The UNIVAC APT III system is written largely in UNIVAC 1107 FORTRAN, known throughout the industry as a leading mathematical program language. Univac has a permanent staff of numerical control experts to assist users in every phase of computer-directed N/C application.

POST PROCESSORS

The following APT III postprocessors are available on the UNIVAC 1107 Computer:

1. The entire family of Cincinnati Acramatic controls (CIMTROL postprocessors).
2. The entire family of General Electric Mark Century contouring controls (GECENT postprocessors).
3. The entire family of Bunker-Ramo (formerly Thompson-Ramo-Wooldridge) controls.

4. Two- and three-axis Bendix BCD Dynapath contouring controls.
5. A complete family of positioning Milwaukee-matic controls, including Model II (Tube-type and solid state), Model III and Model E.
6. A generalized positioning-type system (point-to-point), adapted to Burg, Tape-O-Matic and others. Additional individual point-to-point postprocessors can be readily programmed as extensions of this system.
7. More postprocessors are constantly being added. Consult your local Univac representative for details.

PART PROGRAMMING

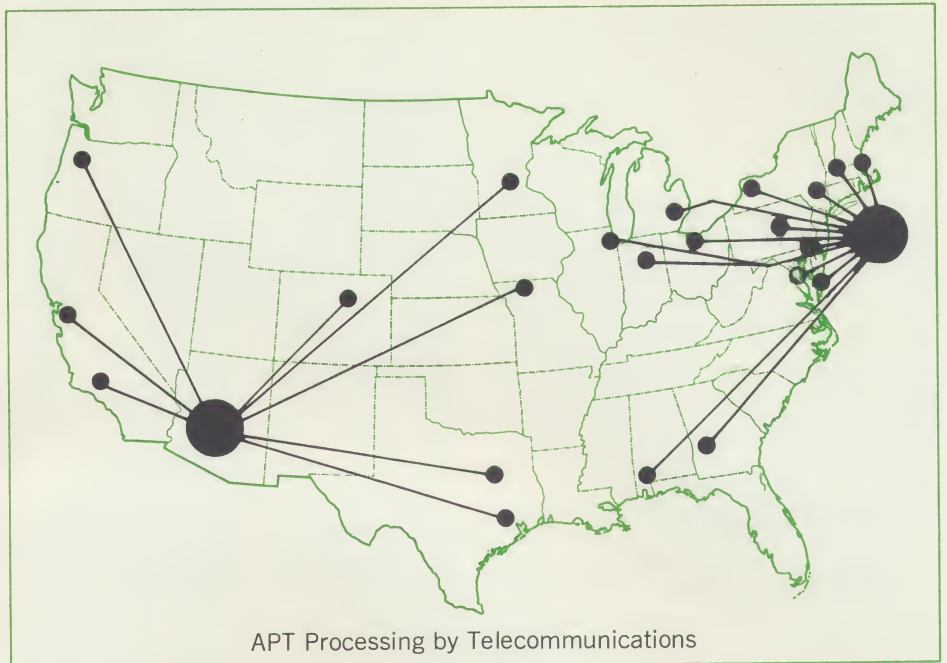
The part programmer plays a vital role in the efficient use of N/C equipment. Production men, familiar with machine tools, are most adept at part programming. UNIVAC Data Processing Centers will help train customer personnel in this work or will arrange to have part programming done by experienced programmers. In-shop programming is recommended for close contact with continuing work, such as checking tapes and problem supervision. UNIVAC Data Processing Centers use the version of APT released for public use, therefore it is not necessary to pay a membership fee to the APT group.

POST PROCESSOR DEVELOPMENTS

UNIVAC N/C experts are ready to develop postprocessor programs rapidly in the compatible FORTRAN language that can be used on any large computer.

REMOTE APT PROGRAMMING THROUGH LOW-COST TERMINALS

APT III is now available to small and medium-sized shops at a fraction of for-



mer cost—and with every convenience of on-site location. A UNIVAC 1004 Processor, located in the user's plant or at a local UNIVAC DPC, is connected to the large-scale UNIVAC 1107 at a central UNIVAC DPC by means of Bell System Data Phones. The user pays only the monthly 1004 rental plus the 1107 Computer time actually used.

equipment on the same telephone line. His APT program is run just as if he were at the large computer. The control tape is then prepared and is ready to be placed on the machine tool. For companies who wish to test APT via remote operation, UNIVAC DPC's and many local Univac offices offer the 1004-1107 connection on a per-hour basis.

With APT III, Numerical Control reaches its peak in power and reliability. And with the UNIVAC 1107 Computer, APT III is implemented with utmost economy and convenience. You can improve your profit picture using the improved numerical control procedures of APT III. Contact your nearest Univac Data Processing Center representative for full information on APT III.

Figure 3 shows how this system works. The user first writes his own part program which is then keypunched into cards. Next, the contents of the cards can be printed on the 1004 Processor to check keypunch accuracy, continuity, etc. He then dials a UNIVAC Data Processing Center and by previous arrangement, data is fed into the Center's

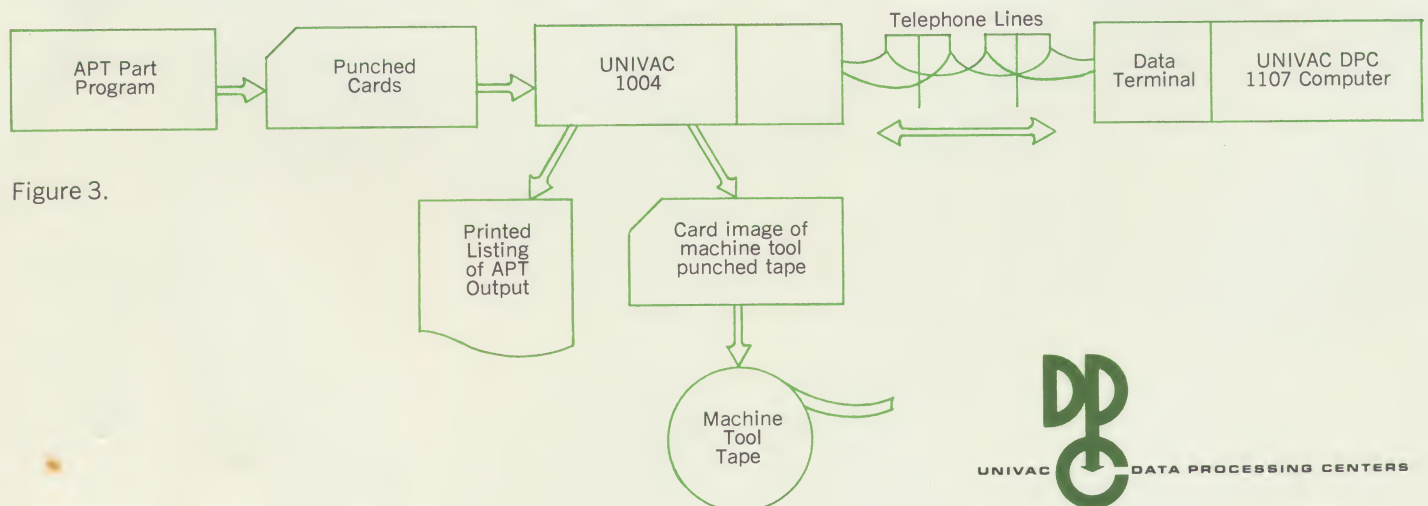


Figure 3.

